

A N
E S S A Y
Of the Great
E F F E C T S
O F
Even Languid and Unheeded
MOTION.

Whereunto is Annexed

An Experimental Discourse
of some little observed Causes of the
Infalubrity and Salubrity of the Air
and its Effects.

By the Honourable *ROBERT BOYLE*,
Fellow of the Royal Society.

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ESSAYS
ON
THE
MOTION

OF THE
HUMAN MIND
IN THE
ACT OF
THINKING

BY
JOHN LOCKE

LONDON
Printed by A. MILLAR, in Strand
1689

ADVERTISEMENT
OF THE
Publisher.

T I S thought fit
the Reader
should be in-
form'd, That the insuing
Tract (about the Effects
of Languid Motions) was
design'd to be a Part of the
Ambour's Notes about the
Origine of Occult Quali-
ties,

Criminal
Qualities
1671
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Advertisement of

ties, and should have come abroad together with the Papers about the Effluvia of Bodies (most of which are already publish'd.) And accordingly it was printed seven or eight years ago: which Circumstance is here mention'd, to give a Reason why several Particulars were omitted in the Body of the Discourse, that will be found annex'd to the End of it. For these occurring to the Author whilst he cursorily read over the Tract it self, when
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to the Publisher.

it was upon the point to be made publick, 'twas thought fit rather to subjoin them by way of a short Appendix, than to let any thing be lost that seem'd pertinent to so difficult and uncultivated a Subject, as That they belong to. The Reader is farther to be advertis'd, That of the Three Preliminary Discourses, which the Author intended for Introductory Ones to What he design'd to say more particularly about the Mechanical Origine or
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Advertisement of
Production of Occult
Qualities, One ~~was~~ con-
cerning the Relations be-
twixt the Pores of Bo-
dies and the Figures of
Corpuscles: but that the
great Intricacy and Diffi-
culty He found in this co-
pious Subject, made Him
consent, That the Dis-
course of Local Motion,
which should have accom-
pany'd it to the Press,
should be printed long before
it. And those Papers about
Pores and Figures having
been for a great while out
of

the Publisher.

of the Author's Power,
He now to gratify the Sta-
tioner with something that
may in Their stead make up
the formerly printed Essay a
Book of a convenient Bulk,
has put into his Hands what
now comes forth, about
some Unheeded Causes of
the Healthfulness and In-
salubrity of the Air :
which being chiefly attribu-
ted to Subterranean Steams,
Subtile and for the most part
Invisible, are as near of kin
to the other Effluvia
treated of in the Introducto-
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ry Discourse, as is requisite
to keep the mention that is
made of them in this Book,
from appearing very incon-
gruous.

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ESSAY

Of the Great

EFFECTS

Of

Even *Languid* and *Unheeded*

LOCAL MOTION.

CHAP. I.

HOW superficially soever the
Local Motion of Bodies is
wont to be treated of by the
Schools, who admit of divers other
Motions, and ascribe almost all strange
things in Physicks to *Substantial Forms*
and *Real Qualities*; yet it will be-
come Us, who endeavour to resolve
the *Phænomena* of Nature into Matter
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2 Of the great Effects

and Local motion, (*guided*, at the beginning of things, immediately, and since *regulated*, according to settled Laws, by the Great and Wise Author of the Universe,) to take a heedfull notice of its kinds and operations, as the true Causes of many abstruse Effects. And though the industry of divers late Mathematicians and Philosophers have been very laudably and happily exercised on the nature and general Laws of this Motion; yet I look upon the Subject in its full extent to be of such importance, and so comprehensive, that it can never be too much cultivated, and that it comprises some parts that are yet scarce cultivated at all. And therefore I am not sorry to find my self obliged, by the design of these Notes, (written, as you know, to facilitate the explicating of *Occult* Qualities) to endeavour to improve some neglected Corners of this vast field, and to consider, Whether, besides those effects of Local motion which are more conspicuous, as being produced by the
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manifest striking of one body against another, where the bulk, &c. of the Agent, together with its Celerity, have the chief Interest; there may not be divers effects, wont to be attributed to Occult Qualities, that yet are really produced by *faint* or *unbeeded* Local motions of bodies against one another, and that oftentimes at a distance.

But, before I enter upon particulars, this I must premise in general, (which I have elsewhere had occasion to note to other purposes,) that we are not to look upon the bodies we are conversant with, as so many Lumps of Matter, that differ onely in bulk and shape; or that act upon one another merely by their own distinct and particular powers; but rather as bodies of peculiar and differing internal Textures, as well as external Figures; on the account of which structures, many of them must be considered as a kind of Engines, that are both so framed and so placed among other bodies, that sometimes Agents, otherwise in-

valid, may have notable operations upon them, because those operations being furthered by the Mechanism of the body wrought on, and the relation which other bodies and Physical Causes have to it, a great part of the effect is due, not precisely to the external Agent, that 'tis wont to be ascribed to, but in great measure to the action of one part of the body it self (that is wrought on) upon another, and assisted by the concurring action of the neighbouring bodies, and perhaps of some of the more Catholick Agents of Nature. This Notion or Consideration being in other Papers particularly confirmed; I shall not now insist upon it, trusting that you will not forget it, when there shall be occasion to apply it in the following Notes.

There may be more Accounts than we have yet thought of, upon which *Local motions* may perform considerable things, either without being much heeded, or without seeming other then faint, at least in relation to the

the considerableness of the Effects produced by them. And therefore I would not be understood in an exclusive sense, when in the following Discourse I take notice but of a few of the above-mentioned Accounts; these seeming sufficient, whereto, as to Heads, may be conveniently enough referred the Instances I allot to this Tract.

And concerning each of these Accounts, I hold it requisite to intimate in this place, that I mention it onely, as that whereon such effects of Local motion, as I refer to it, do principally depend: for, otherwise, I am so far from denying, that I assert, that in divers cases there are more Causes than one, or perhaps than two of those here treated of apart, that may notably concur to *Phænomena* directly referred to but one or other of them.

To come then closer to our subject; I shall take notice, That among the severall things, upon whose account men are wont to overlook or under-

value the efficacy of Local motions, that are either Unheeded or thought Languid, the chief, or at least those that seem to me fittest to be treated of in this Paper, are those that are referable to the following Observations,

CHAP. II.

Observat. I. *Men are not usually aware of the great efficacy of Celerity, even in small Bodies, and especially if they move but through a small space.*

WHat a rapid Motion may enable a Body to doe, may be judged by the powerfull and destructive Effects of Bullets shot out of Cannons, in comparison of the Battering Engines of the Ancients, which, though I know not how many times bigger then the Bullets of whole Cannon, were not able to batter down Walls and Towers like Bullets, whose bulk compared with theirs is inconsiderable. Other examples of

of a like nature might be without impertinency alledged on this occasion; but, because the latter part of our Proposition contains that which I chiefly aim at, I shall proceed to Instances fit to prove That.

I have sometimes caused a skilfull Turner to turn for me an oblong piece of Iron or Steel, and placing my naked hand at a convenient distance to receive the little fragments, perhaps for the most part lesser then small pins heads, as they flew off from the rod, they were, as I expected, so intensely heated by the quick action of the Tool upon them, that they seemed almost like so many sparks of fire; so that I could not endure to continue my hand there. And I remember, that once asking an expert workman, whether he (as I had sometimes done) did not find a troublesome heat in the little fragments of Brass that were thrown off when that metall was turning? He told me, that heat was sometimes very offensive to his eyes and eye-lids. And

when I asked, whether it was not rather as Dust cast into them, than from their Heat; he replied, that besides the stroke, he could sensibly feel a troublesome heat, which would make even his Eye-lids sore: And that sometimes, when he employed a rough Tool, that took off somewhat greater Chips, he had found the heat so vehement, that not onely 'twould scorch his tender Eye-lids, but the thick and hard skin of his hands: for proof whereof he shewed me in one of his hands a little blister, that had been so raised, and was not yet quite gone off.

And inquiring about these matters of a famous Artist, imployed about the finishing up of cast Ordnance, he confess'd to me, That, when with a strong as well as peculiar Engine he and his associates turned great Guns very swiftly, to bring the surface to a competent smoothness, the tools would sometimes throw off bits of metal of a considerable bigness, which, by reason of their bulk and their rapid motion, would be so heated as to burn
the

the fingers of the Country-people that came to gaze on his work, when he, for merriment sake, desired them to take up some of those pieces of metall from the ground. Which I thought the more remarkable, because by the Contact and Coldness of the ground I could not but suppose their Heat to have been much allayed. Not to mention, that I learnt from an experienced Artificer, that in turning of Brass the little fragments of that metall acquire an intenser Heat than those of Iron.

I remember also, that, to vary the Experiment mentioned just before this last, by making it with a bodie far less solid and heavy than Brass or Iron, I caused an Artificer to turn very nimbly a piece of ordinary wood, and holding my hand not far off, the powder, that flew about upon the operation, struck my hand in many places with that briskness, that I could but uneasily endure the Heat which they produced where they hit. Which Heat whether it were com-
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municated from the little, but much heated, fragments to my hands, or produced there by the brisk percussion on my hand, or were the joint effect of both those Causes; it will however be a good Instance of the power of *Celerity* even in very small bodies, and that move but a very little way.

'Tis considerable to our present purpose, that by an almost momentary percussion, and that made with no great force, the parts, even of a vegetable, may be not onely intensely heated, but brought to an actuall Ignition; as we have severall times tried, by striking a good Cane (of that sort which is fit for such Experiments) with a steel, or even with the back of a knife. For, upon this Collision, it would send forth sparks of fire like a flint.

To the same purpose may be alledged, that, by but dextrously scraping good loaf-sugar with a knife, there will be made so brisk an agitation of the parts, that store of sparks will

will be produced. But that is more considerable, which happens upon the collision of a flint and a steel: For, though Vitrification be by Chymists esteemed the ultimate action of the fire, and though, to turn sand or stones, though very finely powdered, into glass, 'tis usually required that it be kept for divers hours in the intense fire of a glass-house; and though, lastly, the glass-men complain, that they cannot bring flints or sand to fusion without the help of a good proportion of *Borillia* or some other fixed salt: yet both actuall Ignition and Vitrification are brought to pass almost in a moment by the bare vehemence of that motion that is excited in the parts of a flint when it is struck with a steel: For those sparks that then fly out, (as an Ingenious person has observed, and as I *Mr. Hooke.* have often seen with a good Microscope,) are usually real and permanent parcels (for the most part globulous) of stone vitrified and ignited by the vehemence of the motion. And that
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this vitrification may be of the stone itself, though steel be a metal of a far more fusible nature then a flint, I am induced to think, because I have tried, that not only flints with steel, but flints with flints, and more easily pieces of Rock-Crystal between themselves, will by collision strike fire. And the like effect of collision I have found my self in some precious stones, harder than Crystall. And afterwards inquiring of an ingenious Artificer that cuts Diamonds, Whether he had not observed the like, when Diamonds were grated on by the rapid motion of his mill? He replied, that he observed Diamonds to strike fire almost like Flints; which afterwards was confirmed to me by another experienced cutter of Gems; and yet having made divers trials on Diamonds with fire, he would not allow that fire itself can bring them to fusion.

Nor are fluid Bodies, though but of small Dimensions, to be altogether excluded from the power of making considerable impressions on solid bodies,

bodies, if their celerity be great.

Whether the Sun-beams consist, according to the Atomical Doctrine, of very minute Corpuscles, that, continually issuing out of the body of the Sun, swiftly thrust on one another in Physically-straight Lines; or whether, as the *Cartesians* would have it, those beams be made by the brisk action of the Luminary upon the contiguous fluid, and propagated every way in straight lines through some Ethereal matter harboured in the pores of the Air; it will be agreeable to either *Hypothesis*, that the Sun-beams, refracted or reflected by a burning-glass to a *focus*, do there, by their concurrence, compose a small portion of fluid matter; and yet the *Celerity*, wherewith the soft and yielding substance is agitated, enables so few of them as can be circumscribed by a Circle, not a quarter of an inch in Diameter, to set afire green wood in lesse than a minute, and (perhaps in as little time as that) to melt not onely Tinn and Lead thinly
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beaten, but, as I have tried, foliated Silver and Gold.

The operation of small portions of fluid matter on solid bodies will be farther exemplified in the IV. *Chapter*, by the effects of the blown flame of a Lamp on glass and metals; so that I shall here need but to point in general at the wonderfull effects that *Lightning* has produced, as well by the Celerity of its motion, as by the matter whereof it consists. Of which Effects, Histories and the writings of Meteorologists afford good store; and I have been an admiring observer of some of them, one of the last of which was the melting of metal by the flame in its passage, which probably lasted but the twinckling of an Eye.

And even a small parcel of Air, if put into a sufficiently-brisk motion, may communicate a considerable motion to a solid body; whereof a notable Instance (which depends chiefly upon the Celerity of the springy corpuscles of the Air) is afforded
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by the violent motion communicated to a bullet shot out of a good wind-gun. For, when this Instrument is well charged, the strongly-comprest Air being set at liberty, and forcibly endeavouring to expand it self to its wonted laxity, its corpuscles give a multitude of impulses to the bullet, all the while that it continues moving along the barrel, and by this means put it into so rapid a motion, that I found by trial, the bullet would in a moment be flatted, almost into the figure of a Hemisphere, by being shot off against a metalline plate.

And farther to shew, How swift that motion must have been, and with what Celerity a vehement agitation may be communicated to the parts of a Solid body, I shall add here (though the *Phænomenon* might be referred to the V. *Chapter*,) that, though the contact of the Bullet and the metalline plate lasted probably but a physical moment; yet the minute parts of the bullet were put into so various and brisk an agitation, that making hast
to

to take it up before it should cool,
I found it too hot to be with over-
much ease held between my fingers.

CHAP. III.

Observat. II. *We are too apt to think, that Fluid bodies, because of their softness, cannot have by their bare motion, especially if insensible, any sensible effect upon Solid ones; though the fluid moves and acts as an intire body.*

TIS not my purpose here to insist on the efficacy of the motion of such fluid bodies as may have their motions discovered by the eye, like streaming water; or manifestly perceived by the touch, as are the winds that beat upon us; since 'twere needless to give Instances of such obvious things, as the great effects of overflowing waters and violent winds; the later of which, notwithstanding the great tenuity and soft-

Softness of the air and the *Effluvia* that swim in it, have been sometimes able to blow down not onely timber-trees, but houses and steeples, and other the firmest Structures. But the motions I intend to speak of in this Chapter are such, as we do not immediately either see or feel; and though these be exceeding rare, yet the operation of *sounds*, even upon solid bodies, and that at a distance from the sonorous ones, afford me some Instances to my present purpose, which I shall now proceed to mention.

It has been frequently observed, that, upon the discharge of Ordnance and other great Guns, not onely the sound may be distinctly heard a great way off; but that, to a good distance, the tremulous motion of the Air that produces sound, without producing any sensible wind, has been able sensibly to shake, and sometimes violently to break, the glass-windows of houses and other buildings, especially when the windows stand in the way

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wherein the propagation of the sound is directly made. 'Tis true, that these observations are most frequent, when the place, where the Artillery is placed, stands upon the same piece of ground with the Houses whose windows are shaken; and so it may be suspected, that the Shake is first communicated by the Cannon to the earth or floor on which they play, and is afterwards by that propagated through the intermediate parts of the ground to the foundations of the houses, and so to the windows. And I readily grant, and may elsewhere shew, that a violent impulse upon the ground may reach to a greater distance than men usually imagine: But in our present Case I see no necessity of having recourse to any thing but the wave-like motion of the Air for the production of our Phenomenon, since the like may be produced by Local Motion transmitted by Fluids, as may appear by the following Instances.

I was once invited by an Engineer,
to

to see triall made of a strange Instru-
ment he had to sink ships, though
great ones, in a few minutes; and
though an unlucky Accident kept
me from arriving there 'till near a
quarter of an hour after the triall had
been made on an old fregat, with bet-
ter successe than my Philanthropy
allowed me to wish; yet causing my
self to be rowed to the place, where
the great vessell was newly sunk;
the odness of the effect, which was
performed upon the water by a small
Instrument outwardly applied, made
me inquisitive, what noise and com-
motion had been made: And I was
informed partly by the Engineer him-
self, and partly by some acquaintances
of mine, who among a great number
of Spectators stood aloof off in ships
and other vessells lying at anchor, to
see the event; that, upon the En-
gine's operating, the explosion was
so great, that it made a kind of storm
in the water round about, and
did so rudely shake vessells that lay at
no inconsiderable distance, as to make

those that stood on them to stagger.

In the late great Sea-fight between the English Fleet commanded by his Royal Highness the Duke of *York*, and the Dutch Admiral *Opdam*, (who therein lost the Victory and his Life,) though the Engagement were made very many Leagues from the *Hague*, yet the noise of the Guns not onely reached to that Place, but had a notable effect there; of which when I enquired of the English Embassadour that as yet resided there, he was pleased to assure me, that it shook the windows of his House so violently, that not knowing what the Cause was, he was surprized and much alarmed, apprehending, that some rude Fellows were about to break his windows to affront him. And if there be a greater disposition in some other bodies than there is in Glass-windows to receive strong impulses from the Air agitated by Sounds, these may be sensibly, though not visibly, wrought upon, and that at a good distance, by the noise of a single piece

piece of Ordnance; as may appear by that memorable Circumstance of an odd Case about a Gangrene mentioned by the experienced *Simon Pauli* in his ingenious Tract *de Febris malignis*, pag. 71. *Atqui aeger ille Gallus brachio truncatus, occiduum quidem superfuit, sed horrendis totius corporis convulsionibus correptus; qui quoque, (ut & illa addam observatione dignissima,) dum in Domini sui adibus ad plateam Kiodmoggerianam, Romanè Laniorum appellares, decumberet, ac, me ac aliis aliquandiu ad Lectum illius confidentibus quidem, sed nobis non attendentibus, exploderentur tormenta bellica ex Regiis ac Prætoriiis navibus, sinistra truncum dextri brachii fovens ac complectens, toties quoties exploderentur singula exclamabat, Au, au, me miserum! Jesu, Maria, contundor penitus: adeò permolesta & intolerabilis illi erat Tormentorum explosio, & quidem ex loco satis longinquo, terrâ non firmâ aut contiguâ, verum super salo aut mari Baltico, instituta.* By this it appears, that the Guns, whose discharge pro-

duced these painfull motions in the Patient, rested upon a floating body, And I remember, that an illustrious Commander of a very great Man of war, being asked by me, whether of the many wounded men, he had in his ship in a very long Sea-fight, none of them were affected by that noise of the Enemy's Cannon discharged in ships at a distance? He answered me, that some, whose bones were broken, would sadly complain of the Torment they were put into by the shake they felt at the going off of the Enemy's Cannon, though they were too much accustomed to the report of great Guns, to be, as 'twas a bare noise, offended by it. If after all this it be surmized, that these motions were not conveyed by the air, but propagated by the water, (and, in some cases, some part of the shoar) from the ships, where the Guns were fired, to the Houses where the windows were shaken, or the places where the wounded men lay: I answer, that, if this could be made probable,

bable, it would accommodate me with very eminent Instances for the Chapter of the *Propagable* nature of Motion: And though it be very difficult to find such examples of shakes excited by sounds as are not liable to the mentioned objection; because the sonorous bodies here below do all either strike, or lean, upon such gross and visible bodies as the Earth and Water; yet there is one kind of Sound, that must be confessed to be propagated by the Air, as being made in it; and that is *Thunder*, whose noise does sometimes so vehemently affect the Air, though without producing any sensible wind, that both others and I have observed it very sensibly to shake great and strong Houses, notwithstanding the distance of the clouds where the noises were first produced. And I remember, that, having inquired of some Sea-Captains, that in stout vessels sailed to the *Indies*, whether they had nor in those hot Regions observed their ships, though very much less tall then

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houses, to be shaken by vehement Thunders? I perceived, that some of them had not much heeded any such thing; but a couple of others told me, they had observed it in their ships; and one of them told me, that once, when the claps of thunder were extraordinary great, some of them shook his ship so rudely as to make the unwonted motions disorder his great Guns. All which I the less wonder at, when calling to mind, what I have mention'd in the foregoing Chapter and elsewhere of the power of the Celerity of motion, I consider, that there is no Celerity that we know of here below, that is near so great, as that wherewith a Sound is propagated through the air. For, whereas the diligent *Mersennus* observes, that a bullet shot out of a Cannon or a Musket does not overpass two hundred and forty yards in a Second, or sixtieth part of a minute; I have more than once diligently observed, that the motion of *Sound* passes above four hundred yards in the same

same time of a Second here in *England*; which I therefore add, because *Mersennus* relates, that in *France* he observed a Sound to move in that time many yards more; which may possibly proceed from the differing consistence of the English air and the French.

The great Loudness of these sounds, and the vehement percussion that the Air receives in their formation, will probably make it be easily granted, that 'twas onely the Impetuosity of the motion of the *Medium*, that gave the shake to the windows and other solid bodies that I have been mentioning to have been made to tremble by the report of Cannon or Thunder: But yet I will not on this occasion conceal, that perhaps it may without absurdity be suspected, that Some of those tremulous motions of solid bodies might either depend upon, or at least be promoted by, some peculiar disposition, that Glasse (which is endued with springiness,) and some other bodies that perhaps are not quite devoid of that Quality, may

may have to be moved by certain congruous Sounds (if I may so call them) more than they would by others, though perchance more loud. But though this surmize should be admitted; yet it would not render the lately-recited Instances improper for the design of this Discourse, but onely would make some of them fit to be referred to another *Chapter*; to which I shall advance, as soon as I shall have annexed an odd Observation of the experienced *Platerus*, which argues, that, where there is a peculiar Disposition, even in a firm body, it may receive considerable impressions from so languid a motion (though in likelihood not peculiarly modified) of the air as is not sensible to other bodies of the same kind.

Plater. Observ. Fæmina quædam (says he)
 Lib. 1. p. 185. *in subitaneum incidit morbum, viribus subito prostratis, se suffocari indesinenter clamitans, etsi nec stertoris nec tussis aliqua essent indicia; maxime verò de aura quædam adveniente, si vel leviter aliquis adstantium se moveret,*

moveret, quæ illam opprimeret, conquereretur, seque suffocari, si quis propius accederet, clamitabat: vix dum biduum in ea anxietate perseverans, expiravit. To which he adds: *Vidi & alios egros, de simili aura, quæ eos, si quis illis appropinquaret, in suffocationis periculum induceret, conquerentes; quod semper pessimum esse signum deprehendi.*

CHAP. IV.

Observat. III. *Men undervalue the motions of bodies too small to be visible or sensible, notwithstanding their Numerousness, which enables them to act in Swarms.*

MOST men, when they think at all of the effluvia of bodies and their motions, are wont to think of them as if they were but much finer sorts of Dust, (whose grains, by reason of their smallness, are invisible,) which, by the various agitation of the Air, are
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as 'twere by some faint wind blown against the surfaces of the bodies they chance to meet in their way, and that they are stopped in their progress without penetrating into the interior parts of the bodies they invade. And according to this Notion, 'tis no wonder, that men should not fancy, that such minute bodies passing, as they suppose, no further than the surfaces of those on which they operate, should have but faint operations upon them.

But we may have other thoughts, if we well consider, that the Corpuscles we speak of, are, by their minuteness, assisted, and oftentimes by their figure enabled, to pierce into the innermost recesses of the body they invade, and distribute themselves to all, or at least to multitudes of the minute parts, whereof that body consists. For this being granted, though we suppose each single *effluvium* or particle to be very minute; yet, since we may suppose, even solid bodies to be made up of particles that are so too, and the number of invading particles
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to be not much inferior to that of the invaded ones, or at least to be exceedingly great, it need not seem incredible, that a multitude of little Corpuscles in motion (whose motion, may, for ought we know, be very swift) should be able to have a considerable operation upon particles either quiescent, or that have a motion too slow to be perceptible by sense. Which may perhaps be the better conceived by the help of this gross example :

If you turn an Ant-hill well stocked with Ants-eggs, upside down; you may sometimes see such a heap of eggs mingled with the loose earth; as a few of those Insects, if they were yoked together, would not be able at once to draw after them; but if good numbers of them disperse themselves and range up and down, and each lay hold of her own egge; and hurry it away, 'tis somewhat surprizing to see (as I have with pleasure done) how quickly the heap of eggs will be displaced, when almost every little egge has
one

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one of those little Insects to deal
with it.

And in those cases, wherein the invading Fluid does not quite disjoin and carry off any great number of the parts of the body it invades, its operation may be illustrated by that of the wind upon a tree in *Autumn*: for, it finds or makes it self multitudes of passages, for the most part crooked, not onely between the branches and twigs, but the leaves and fruits, and in its passing from the one side to the other of the tree, it does not onely variously bend the more flexible boughs and twigs, and perhaps make them grate upon one another, but it breaks off some of the stalks of the fruit, and makes them fall to the ground, and withall carries off divers of the leaves, that grew the least firmly on, and in its passage does by its differing parts act upon a multitude of leaves all at once, and variously alters their situation.

But to come to closer Instances:
sup-

even languid Local motion. 31

suppose we cast two lumps, the one of Sugar, the other of Amber, into a glass of beer or water, they will both fall presently to the bottom. And though perhaps the Amber may be lighter than the Sugar, (for, I have found a notable difference in the specific gravity of pieces of Amber,) yet the aqueous particles are far from being able to displace the Amber or any sensible part of it, or exercise any visible operation upon it: But the same minute particles of the liquor being of a figure that fits them to insinuate themselves every way into the pores of the Sugar, though the lump consisted of very numerous Saccharine Corpuscles, yet the multitude of the aqueous particles, to which they are accessible, is able in no long time to disperse them all, and carrying them along with themselves, make the whole lump of Sugar in a short time quite disappear.

The point above discoursed of, may be more nimbly exemplified in some Chymical operations, and particu-

ticularly in this. If, by a due degree of fire, you abstract from running Mercury four or five times its weight of good Oil of Vitriol, there will remain at the bottom a dry and brittle substance exceeding white; and, if upon this Heap of Mercurial and Saline bodies, which sometimes may be coherent enough, you pour a good quantity of limpid water, and shake them together, you may see in a trice the multitude of little white grains, that make up the masse, pervaded, and manifestly altered, by the dispersed Corpuscles of the water; as will plainly appear by the change of the *Calx* or *Precipitate* from a white masse into one of a fine Limon-colour.

But to give instances in Fluid bodies, (which I suppose you will think far the more difficult part of my task,) though you will easily grant, that the flame of Spirit of wine, that will burn all away, is but a visible aggregate of such *Effluvia* swiftly agitated, as without any sensible Heat
would

would of themselves invisibly exhale away; yet, if you be pleased to hold the blade of a knife, or a thin plate of Copper, but for a very few minutes, in the flame of pure Spirit of wine, you will quickly be able to discern by the great Heat, that is, the various and vehement agitation of the minute Corpuscles of the metal, what a number of them must have been fiercely agitated by the pervasion of the igneous particles, if we suppose, (what is highly probable,) that they did materially penetrate into the innermost parts of the metal; and whether we suppose this or no, it will, by our experiment, appear, that so fluid and yielding a body, as the flame of Spirit of wine, is able, almost in a trice, to act very powerfully upon the hardest metals.

The power of extreamly-minute parts of a fluid body, even when but in a moderate number they are determined to conspire to the same operation, may be estimated by the

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motions of Animals, especially of the larger and more bulky sorts, as Horses, Bulls, Rhinocerots and Elephants. For, though the animal spirits be minute enough to be invisible, and to flow through such tender passages, that prying Anatomists have not been able in dissected Nerves to discern so much as the channels through which they pass; yet those Invisible Spirits, conveyed (or impelled) from the Brain to the Nerves, serve to move in various manners the Lims, and even the unwieldy bodies themselves of the greatest Animals, and to carry them on in a progressive motion for many hours together, and perhaps enable them to spring into the Air, and move through it by leaping; though divers of these Animals weigh many hundred, and others several thousand of pounds.

I will not here consider, whether the following Experiment may at all illustrate Motions that are produced by the fluid parts of Animals in some
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of the consistent ones : But I presume, it may confirm the Observation maintained in this Chapter, if I add, what I have tried of the considerable force of a number of aqueous particles, as flexible and as languid as they are thought to be, insinuating themselves into the pores or Intervals of a rope that was not thick. For in moist weather I sometimes observed, that the aqueous and other humid particles, swimming in the air, entering the pores of the hemp in great numbers, were able to make it shrink, though a weight of fifty, sixty, or even more pounds of lead were tied at the end to hinder its contraction, as appeared by the weights visibly being raised in wet weather above the place it rested at in dry.

But to return to what I was formerly speaking of the Determination of the motion of Fluids; I shall, on this occasion, observe, that, though the wind or breath, that is blown out at a small crooked pipe of metal or glass, such as Tradesmen for its

use call a Blow-pipe, seems not to have any great celerity, especially in comparison of that of the parts of flame; and is it self of little force; yet, when by this wind the flame of a Lamp or Candle is directed so as to beat with its point upon a body held at a convenient distance from the side of the flame, the burning fluid, determined, and perhaps excited by this wind, acquires so great a force, that, as we have often tried, it may be made, in a few minutes, to melt not onely the more fusible Metals, but silver, or even copper it self; which yet may be kept for many hours unmelted in a Crucible kept red-hot, or even in the flame of the Lamp or Candle, unassisted by the blast.

And if we can so contrive it, that a flame does not come to invade onely the surface that invests a body, but comes to be intermingled with the smaller (though not the smallest) parts it consists of, as with its filings or its powder; the flame will then have a far more quick and powerfull
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operation than the body exposed to it. This I exemplify (in other Papers) and in this place it may suffice to observe, that, whereas a pound or two of Tartar may cost you some hours to calcine it to whiteness, if the flame have immediate access onely to the outward parts; you may calcine it in a very small part of that time, if, mixing with its gross powder an equal weight of good Salt-peter, you fire the mixture, and keep it stirring, that the parts of the kindled Nitre may have access at once to very many parts of the Tartar, and have opportunity to calcine them. And by somewhat a like artifice, I elsewhere teach, how Nitre it self may without Tartar be speedily reduced to a *Calcinatum*, not unlike that newly mentioned. But it may be said, that some of the foregoing Instances (for it cannot be truly said of all) may indeed illustrate what we are discouraging of, but will not reach home to our purpose.

I shall therefore consider the

Load-stone, which you acknowledge to act by the emission of Insensible particles. For, though Iron and Steel be solid and ponderous bodies, and *Magnetical effluvia* be corpuscles so very minute, that they readily get in at the pores of all kind of bodies, and even of Glass it self; yet these *Magnetical effluvia*, entring the steel in swarms, do in a trice pervade it, and a multitude even of Them, acting upon the Corpuscles of the metal, do operate so violently on them, that, if the *Load-stone* be vigorous enough, and well capped, it will attract a notable proportion of steel, and surmount the gravity of that solid metal, which I have found to exceed, when the stone has been very good and little, above fifty times the weight of the Magnet by whose *effluvia* it was supported: For, to these I rather ascribe *Magnetical attraction* and sustentation, than to the impulse or pressure of the ambient air, to which many *Corpuscularians* have recourse; because I have found by trial (which
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even languid Local motion. 39

I elsewhere relate) that the pressure of the ambient air is not absolutely necessary to Magnetical operations.

I remember, that, to help some friends to conceive, how such extremely-minute particles as Magnetical *effluvia*, may, by pervading a hard and solid body, such as Iron, put its insensible Corpuscles into motion, and thereby range them in a new manner, I took filings of Steel or Iron freshly made, that the Magnetical virtue might not be diminished by any rust, and having laid them in a little heap upon a piece of paper held level, I applied to the lower side of the paper, just beneath the Heap, the pole of a vigorous Load-stone, whose Emissions traversing the paper, and diffusing themselves through the incumbent metall, did in a trice manifestly alter the appearance of the Heap; and, though each of the filings might probably contain a multitude of such small Martiall Corpuscles as Steel may be divided into by Oil of Vitriol or Spirit of Salt; yet the Mag-

netical *effluvia*, immediately pervading our metalline heap, did so remove a good part of the filings that composed it, as to produce many erected aggregates, each of which consisted of several filings placed one above another, and appearing like little needles, or rather like the ends of needles broken off at some distance from the point. And as these little temporary needles stood all of them erected (though more or less, according to their distance from the Pole of the Magnet) upon the flat paper; so they would, without losing their figure or connexion, be made as it were to run to and fro upon the paper, according as the Load-stone, that was held underneath it, was moved this way and that way; and as soon as that was taken quite away, all this little stand of pikes (if I may so call it) would (almost in the twinkling of an eye) relapse into a confused heap of filings.

There are two ways of explicating the turning of Water into Ice; one
or

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or other of which is approved almost by all the Corpuscularian Philosophers. The first is that of the *Cartesians*, who give an account of Glaciation by the recesses of the less subtile particles of the Etherial matter, without which the finer parts were too small and feeble to keep the Eel-like particles of water flexible, and in the form of a liquor. The *Atomists* on the other side ascribe the freezing of water to the ingress of multitudes of *frigorifick* Corpuscles, as they call them, which, entering the water in swarms, and dispersing themselves through it, crowd into the pores, and hinder the wonted motion of its parts, wedging themselves (if I may so speak) together with them into a compact body. But which soever of these two *Hypotheses* be pitched upon, the Phenomenon it self will afford me a notable Instance to my present purpose. For, the Particles of water, and much more the Corpuscles of cold, are confessed to be singly too small to be visible,

visible, and their motions are not said to be swift, but may rather be judged to be slow enough ; and yet those minute aqueous, or more minute frigorifick particles, because of their number, produce in the glaciation of the liquour so forcible a motion outwards, as to make it break bottles, not onely of glass and earth strongly baked, but, as I have several times tried, of metal it self, that being full of the liquour were firmly stopped before the supervening of the Cold. And the expansive endeavour of freezing water is not onely capable of doing this, but of performing so much greater things, which I elsewhere relate, that my trials have made me sometimes doubt, whether we know any thing in nature, except kindled Gunpowder, that bulk for bulk moves more forcibly, though the motion seems to be very slow.

CHAP. V.

(Of the Propagable Nature of Motion.)

Observat. IV. *Men are not sufficiently aware, how propagable Local Motion is, even through differing Mediums, and Solid bodies.*

THere are four principal Occasions on which I have observed, that men are wont to think the Communicating of Motion much more difficult than indeed it is.

And *first*, there are many, that observing how usually those bodies that hit against hard ones rebound from them, easily perswade themselves, that Motion can scarce be transmitted or diffused through Solid bodies. But though it be true, that oftentimes in such cases the progressive motion of the body or the Solid,

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Solid, that is struck or impelled, be either inconsiderable, or, perhaps, not so much as sensible; yet the impulse may make a considerable impression, and may be communicated to a great share of the particles of that matter, whereof the solid mass consists; as we see in the striking of a timber-beam at one end, the motion, though perhaps it were not strong at the first, may become sensible at the other. Though Bell-metal be so hard a body, that it is reckoned harder than iron it-self, insomuch that oftentimes it resists even files of Steel, which readily work on Iron; yet this solidity hinders not but that, as I have found, conveniently shaped vessels of Bell-metal, though thick, will be sensibly affected by a motion that neither is strong, nor touches them in more than a short line, or perhaps than a Physical point. The truth of this I have found by trial on more than one such vessels and particularly on one that was hemispherical, which being placed or held in a convenient posture,

posture, if I did but gently pass the point of a pin for a little way along the brim of it, it would sensibly resound, and that (to a very attentive ear) so long, and in such a ringing manner, as made it highly probable, that the parts, immediately touched (and not so much as scratched) by the point of a pin, were not onely put into a vibrating motion themselves, but were enabled to communicate it to those that were next them, and they to those that were contiguous to them; and so the tremulous motion was propagated quite round the bell, and made divers successive Circulations before it quite ceased to be audible. And if, in stead of drawing a Line on the brim of the vessel, I struck it, though but faintly, with the point of a pin, though the part immediately touched would be but a physical point, yet the motion would be, like the former, propagated several times quite round; as was argued by the ringing and duration of the produced sound, though this metal-

metalline vessel were seven inches in Diameter, and of a considerable thickness. Nor was a solidity like that of Brass requisite to produce these effects. For I found them to insue much after the same manner, when I employed onely a short and slender thread of Glass, which though little, if at all, thicker than a pin, was yet hollow quite through. Now if it be true, as 'tis highly probable, that Sound, as it belongs to the air, consists in an undulating motion of the Air, and so in our case requires a vibrating motion in the sonorous body to impart that motion to the Air; we must grant in our Instances a wonderfull propagableness of motion, even when 'tis not violent, in Solid bodies themselves; since the point of a pin, gently striking a part, no bigger than it self, of a mass of very solid metal, could thereby communicate a sensible motion, and that several times circulated, to millions of parts equall to it in bulk, and much exceeding it in hardness. And since
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the effect was more considerable, when the trial was made in a much greater, than in a smaller vessel; 'tis probable, that, if I had had the opportunity of experimenting on a large and well-hung Bell, the *Phenomenon* would have been more notable; as it also seemed to be on our vessel, if, in stead of striking it with the point of a pin, we cast, though but faintly, against the lower part of it a grain of shot, less than a small pins-head, or let a little grain fall, from about one foot high, upon the inside of the inverted Hemisphere. And to shew, that even soft and yielding bodies, and but faintly moved, are not to be excluded from a power of putting such hard ones into motion; I shall add, that I found almost the like effects to those above mentioned, by passing the pulp of my finger a little way along the lower part of the vessel. Nay, that fluid bodies themselves may communicate such an intestine and propagable motion, to harden solid ones, I may have hereafter

after an occasion to shew by the effects of a small Flame, and the Sun-beams on glass and steel. And I shall here on this occasion add this word about the Propagation of Motion produced in solid bodies by heat, that it much depends upon the particular Textures of the bodies. For I found, that when I heated a piece of glass or of a fire-stone, I could without inconvenience hold my naked hand upon parts that were very near (suppose within an inch off) the ignited portions of them. But, if we take a rod of Iron, for instance, and heat one end red-hot, the heat of that end will be so propagated towards the other, that it will offend one's hand at several times the distance, at which one might conveniently hold the rod, if it were of glass.

In many buildings it may be observed, (and is thought a sign of the firm Cohesion of their parts,) that a stamp of one's foot, nay or bare treading, or some such other lesse brisk impulse, made in one room, will

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will have a sensible effect in all or most of the others. And it often happens, that, by the hasty shutting of a door, the whole house is made to tremble; whence we may argue, that, even among solid bodies, motion made in one place may be readily propagated to many others: And if, as to the latter of the Instances, the sudden impulse and compression of the Air, made by the door supposed to be hastily shut, have any considerable share in the effect, the Phænomenon will serve to shew the efficacy even of such a motion of a fluid body, as we cannot directly feel upon divers large and firmly connected solid bodies.

In *Earthquakes* the tremulous motion sometimes extends so very far, that, though it seems highly probable, that the shake that is given to one part of the Earth by the firing and explosion of subterranean exhalations, (if that be the true and only cause of Earthquakes) is not capable of reaching near so far as divers

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Earthquakes have done, but that the fire passes through some little subterranean clefts, or channels, or hidden conveyances, from one great Cavity or Mine to another; yet 'tis not improbable but that the vehemently tremulous motion does oftentimes reach a very great way beyond the places where the explosions were made. Since, though *Seneca* would

Natur. Quest. Lib.
VI. Cap. 25.

confine the extent of Earthquakes to two hundred miles, yet observations made in this and the last Century warrant us to allow them

Lib. III.
Cap. 26.

a far greater spread. The Learned *Josephus Acosta* affirms, that in the Kingdom of *Peru* in the year 1586 an Earthquake reached along the shoar of the Pacifick sea 160 Leagues; and adds, that sometimes it has in those parts run on from South to North 300 Leagues. And in the beginning of this our age (*Anno Dom. 1601*) good writers relate a much larger Earthquake to have happened, since it reached from

Asia

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Asia to that Sea that washes the French Shoars, and, besides some *Asiatick* Regions, shook *Hungary*, *Germany*, *Italy* and *France*, and consequently a great part of *Europe*. And if that part of the Narrative be certain, which relates, that this lasted not much above a quarter of an hour, it will be the more likely, that this Earthquake shook great Tracts of Land beyond those places, to which the fired matter, passing from one cavity to another, could reach in so short a time: As you will the more easily guesse, if you try, as I have done, that in trains of Gunpowder it self the fire does not run on near so swiftly as one would imagine. But though I have been in more Earthquakes then one; yet, since they were too sudden and too short to afford me any considerable observation, I shall say no more of them; but proceed to take notice, that oftentimes the motion of a Coach or Cart, that passed at a good distance from the place that I was in, has made the

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buildings

buildings so sensibly shake, that I could not but wonder, that so great a portion of so firm and sluggish a body, as the Earth, could, by a cause that seemed very disproportionate to such an effect, be made to tremble it self, and manifestly to shake firm buildings that were founded on it. And this observation made me the more inclinable to give credit to their Relations, who tell us, that in a calm night, the march of a troupe of horse may be felt, by attentive Scouts watching at a great distance off, by the shake that the ground receives from the trampling of the horses; though I formerly suspected much, and do yet a little, that the impulse of the air conveyed along the resisting surface of the ground, might mainly contribute to the effect that is ascribed onely to the motion of the soil.

Before I advance to the *Second* Member of this Chapter, it may not be impertinent to note, that in peculiarly disposed bodies, and especially in Organical ones, a very languid
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motion may have a far greater effect, than it could produce by a bare propagation of it self. For it may so determine the motion of the Spirits or other active parts of the body it works on, as to make multitudes of them act as if they conspired to perform the same motions. As when a ticklish man, by having the pulp of one's finger passed gently along the sole of his foot or the palm of his hand, has divers muscles and other parts of his body and face put into preternatural or unusual motions. And most men by being lightly tickled with the end of a feather or straw, within their Nostrils, have their heads and many parts of their bodies put into that violent Commotion, wherein *Sneezing* consists. And I remember, that having for some time been, by a distemper, (from which God was graciously pleased a while after to free me,) quite deprived of the use of my hands; it more than once hapned to me, that sitting alone in a Coach, if the wind chanced to

E 3 blow

blow a single hair upon my face in the Summer-time, the tickling or itching, that it produced, was so uneasy to me, 'till by calling out to a footman I could get it removed, that, though I could well bear it as long as I was wont to do, when, having the use of my hands, I could relieve my self at pleasure; yet if I were forced to endure the itching too long, before any came to succour me, the uneasiness was so great, as to make me apprehend falling presently either into Convulsions or a Swoon. But 'tis time to proceed to the *second* Member of this Chapter.

2. Others there are, that cannot believe, that Local motion, especially if it be *languid*, can be propagated through differing Mediums, each of which, save that wherein the Motion is begun, must, they think, either repell, or check and dead it. To these I shall recommend the Consideration of an Experiment, I remember I made before some Learned men in our Pneumatick Engine. For, having

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caused a large and thick glass Receiver to be so blown, that it had a glass button in the inside of that part which upon the Engine was to be placed upwards; I caused a Watch to be suspended by a little Silver-chain fastned to that button by as slender and soft a body, as I thought would be strong enough to support my watch; and then, the Glass being cemented on close to the Receiver, to prevent a Commerce between the Cavity of it and the Air, the watch, that hung freely near the middle of the Cavity of the Receiver, made it self to be heard by those attentive Listners, that would hold their ears directly over the suspended watch, whose motions were thereby argued to have been propagated, either through the included air, or along the string to the concave part of the Glass, and through the whole thickness of the Glass to the convex part, and thence, through the interposed air to the Ear. And this mention of watches minds me of what I often ob-

served in a small striking watch, that I have worn in my pocket. For, when it struck the Hours, and in some postures when the balance did but move, I could plainly feel the brisker motions of the Bell, and sensibly the languid ones of the balance, through the several linings of my Breeches, and some other interposed soft and yielding bodies; and this, though the watch (as I said) was small, and the balance included in a double case, and though the outwardmost were of (what they call) Chagrine, and the innermost of Gold; which I therefore mention, because that closest of metals is observed more to dead sounds and motions than harder metals, as Silver, Copper, and Iron.

That Motion may be propagated through differing Mediums, may seem the more probable by the shakings that are often felt by men lying on beds that stand in rooms close shut, when loud claps of thunder are produced (perhaps at a great distance off) in the clouds. And whether it
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will be fit to add to this Instance^e that which you have lately met with in the III. Chapter of a wounded Frenchman at *Copenhagen*, I leave you to consider.

I know not whether it will be very proper to take notice on this occasion of an odd *Phænomenon* recited by the experienced *Agricola* De nat. eorum in these words. *Si animal quæ est. è Terra dejicitur in antrum Vi-* Lib. IV. Cap. 7. *burgense, quod est in Carelia, Regione Scandia, erumpit, ut perhibent, sonus intolerabilis magno cum flatu: Si leve pondus in specum Dalmatiæ, quamvis, inquit Plinius, tranquillo die, turbini similis emicat procella.*

3. As those of whom I took notice at the beginning of this Chapter, are backward to allow, that Motion may be considerably propagated through *solid* bodies; so on the contrary, there are others that are indisposed to think, that 'tis near so propagable as indeed it is through *fluid* bodies; because they presume, that the easy cession of the parts of fluids will

will dead the impulse received by those of them that are first acted on by the impelling body. And

4. There is yet another sort of Naturalists, who, though they may be brought to grant, that Motion may be propagated even through a soft and yielding Medium, cannot believe, that it should through such a Medium be propagated to any considerable distance; being perhaps induced to this opinion by observing, that, though a body somewhat broad as well as solid, as the Palm of one's hand or a battledore, be moved through the Air swiftly enough to make a wind; yet that wind will not be strong enough to be felt any more than a very little way off. Wherefore, because the Instances, to which I assign the remaining part of this Chapter, may be for the most part applicable to the removal of both these prejudices; It may for brevity sake be expedient to consider them both together.

If Luminous bodies act on our
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Eyes, not by a substantial diffusion of extremely minute particles, as the *Atomists* would have it, but by a propagated Pulsion of some Subtile matter contiguous to the shining body, (as the *Cartesians* and many other Philosophers maintain;) 'twill be manifest, that a body less than a small pin's head may give a brisk motion to a portion of fluid matter many millions of times greater than it self; since in a dark night a single spark of fire may be seen in differing places, whose distance from it exceeds many thousand times the spark's *Diameter*. Not to mention the great remove, at which the flame of a small taper may not onely be seen, but appear greater than near at hand. And if we compare the *Diameter* of that bright Planet *Venus*, which yet shines but with a borrowed and reflected Light, with its *distance* from the Earth, we may easily conclude, that the fixed Stars, which probably are so many Suns that shine by their own native Light, must impell a stupendous

pendious proportion of Etherial matter, to be able at that immense distance to make such vivid Impressions, as they do, upon our Eyes. But to descend to Instances less remote and disputable, I shall, in order to the removal of the two lately mentioned prejudices, proceed to consider; that, though it be true; that Fluid bodies do easily yield to Solid ones that impell them, and thereby oftentimes quickly dead the motion of those Solids; yet the motion, being lost onely in regard of the solid body, is not lost, but transmitted and diffused in reference to the fluid. As when a log of wood, or any such body specifically lighter than water, is let fall in the middle of a pond, though its progress downwards be checkt, and it be brought to rest quietly on the surface of the water; yet its motion is not lost, but communicated to the parts of the water it first strikes against, and by those to others, till at length the curls or waves produced on the surface of the water

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ter spread themselves, till they arrive at the brinks, and would perhaps be farther expanded, if these did not hinder their progress. From which instance we may learn, that, though the nature of fluid bodies, as such, requires, that their parts be actually distinct and separately moved; yet the particular Corpuscles that compose them, being (at least here below) touched by divers others, the new motion that is produced in some of them by an impellent Solid, must needs make them impell the contiguous Corpuscles, and these those that chance to lie next to them, and so the impulse may be propagated to a distance; which you will the more easily believe may be great, if you consider with me, both that in a fluid body the Corpuscles, being already in the various motion requisite to fluidity, yield more easily to the impellent, and also that being fully, or very near it, counterpoised by others of the same fluid, a scarce imaginably little force may suffice to impell them;

them; insomuch that, though the brass Scale of a balance, of divers inches in Diameter, may well be supposed to outweigh many myriads of such particles as compose water, wine, &c. yet, (as I elsewhere more fully relate) when such a scale was duly counterpoised with another like it, I could easily put it into various motions onely with the invisible *Effluvia* of no great piece of Amber. And if we consider that obvious Instance of the swelling Circles made by casting a stone into a Pond or other stagnant water, we shall be the more easily perswaded, that, even in a heavy fluid, a motion may reach a far greater way, than men are usually aware of, beyond the parts on which it was first impress.

On this occasion I must not omit a strange Observation given me by a very experienced Navigator, that much frequents the Coast of *Groenland*, and other *Arctick* Regions, to fish for whales. For this person being discoursed with by me about the effects

fects of the breaking of those vast piles of Ice, that are to be met with in those parts, assured me, that not onely he had often heard the Ice make in breaking terribler noise than the loudest claps of thunder with us, but that sometimes, when the Sea-water had, as it were, undermined the foundation of the mountainous piece of Ice, he has known it at length suddenly fall into the subjacent Sea with so much violence as to make a storm at a great distance off; inso-much that once, when he lay two Leagues off of the place where this stupendious mass of Ice fell, it made the waves goe so high as to wash clear over the stern of the ship, with danger enough to some of his men, and to sink several of his shallops that were riding by, though scarce any small vessels in the world use to be so fitted for rough Seas as those about *Groenland*.

And whereas, though the Air be a much thinner fluid, we are apt to think it indisposed to propagate motion

tion far, give me leave to tell you, that we may take wrong measures, if we think, that, (for instance) the undulating motion, into which the Air is put by the action of sonorous bodies, reaches but a little way, as we are apt to presume it does, because we judge of it by the effect it has on our ears when the sound is made in disadvantageous places. For one, that, for instance, hears a Lute or a Viol plaid on in a room furnished with hangings, will be apt to think the sound faint and languid in comparison of what it would appear to him, if the same Instrument were plaid on after the same manner in an arched room without hangings; these soft and yielding bodies being apt to dead the sound, which the figure and hardness of the Vaulted room would reflect. And so, when a man speaks aloud in the free Air, we are not wont to take any notice of a progress made by the motion of the Air beyond the place we are in, when our ears receive the sound; but if the place happen
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even languid Local motion. 65

to be furnished with an *Echo*, though at many times that distance from the speaker, we may then easily take notice, that the motion of the Air was carried on, and that with good vigour, to a far greater distance than else we should have observed. And I have often thought, that, even by the better sort of our Echoing places, we are not informed, to near how great a sphere the motion, which the Air is put into by Sounds, may extend it self, where its diffusion and vigour are not hindred nor weakned by bodies either placed too near, or indisposed to promote its operation.

What has been lately said of the great diffusion of Sounds, if themselves be loud and great, will appear highly probable, by what is related by the Learned *Fromundus*,
who being Professour of *From. Meteor.*
Lib. II. Art. 9.
Philosophy at *Lovain*, in
the Year 1627, had opportunity
enough to know the Truth of what
he relates; namely that, at the famous Siege of *Ostend* in *Flanders*, the
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thunder of the great Ordnance was heard at above thirty Dutch Leagues, which, according to the vulgar reckoning, amounts to a hundred and twenty of our English miles. And that is yet, as he truly observes, more strange, and makes more for our present purpose, which he adds concerning the diffusion of the sound of a Drum, which, he says, was, upon a time, heard at Sea twelve Leagues off.

But to return to what I was saying of *Echo's*, to confirm my conjecture about them, I shall think it needlesse to offer you any other Argument, than that which you will draw your self from the Notable Relation I met

with in the Learned *Va-*
Geograph. general. Lib. I. Cap. XIX. renius of an Observation
 made by *David Fralechi-*

us, who, in the Company of a couple of Students, had the curiosity (in the month of June) to visit the mountain *Carpathus*, esteemed the highest of all the *Hungarian Hills*, and said to be much more steep and difficultly ac-
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cessible than any of the *Alps* themselves. *Frælichius* then (in my Author) having related with what difficulty he and his Companions ascended above that Region of the Air, where they met with clouds and vehement winds, adds this memorable Observation, for whose sake I mention the story : *Explosi* (saies he) *in ea summitate sclopetum, quod non majorem sonitum primò præ se tulit, quàm si tigillum vel bacillum confregissem ; post intervallum autem temporis murmur prolixum invaluit, inferioresque montis partes, convalles, & sylvas oplevit. Descendendo per nives annosas intra convalles, cùm iterum sclopetum exonerarem, major & horribilior fragor quàm ex tormento capacissimo inde exoriebatur : hinc verebar, nè totus mons concussus mecum corrueret ; duravitque hic sonus per semiquadrantem horæ, usque dum abstrusissimas cavernas penetrasset, ad quas Aer undique multiplicatus resiliit. Et talia quidem objecta concava in summitate se non illico offerebant, idcirco ferè insensibiliter*

Of the great Effects of
*primum sonus reperiiebatur, donec
 descendendo antris & convallibus vi-
 cinior factus, ad eas fortius impegit.*

CHAP. VI.

Observat. V. *Men usually think not
 what the modification of the invis-
 ible motion of Fluids may perform on
 the disposed bodies of Animals.*

IN this Observation I expressly men-
 tion *the disposed bodies of Ani-
 mals*, to intimate, that there is a peculi-
 ar aptitude required in those Animals,
 or some particular parts of them that
 are to be sensibly affected by such
 motions as we are treating of, which
 would otherwise be too languid to
 have any sensible operation on
 them.

It seems the less strange to me, that
 continuing Sounds, and other some-
 what durable Impulses of the Air or o-
 ther Fluids, should have a manifest ope-
 ration upon Solid bodies, when I consi-
 der

der the multitude of strokes that may in a very short and perhaps scarce observable time, be supposed to be given by the parts of the fluid to the Consistent body. For, though each of these single would perhaps be too languid to have any sensible effect at all; it being opportunely and frequently repeated by the successive parts of the fluid, as by so many little swimming hammers or flying bullets, they may well have a notable effect upon the parts of a body exposed to their action: As may be argued from the great swing that may be given to Pendulums by a very languid force, if it successively strike the swinging body, when having finished its excursion, 'tis ready to return towards the Perpendicular; as also from the tremulous motion that is imparted even to the metalline string of a Musical Instrument, by the congruous motion the Air is put into by another trembling string, (as there may be hereafter occasion to declare.)

I remember, *Scaliger* tells a pleasant

fant story of a Knight of *Gascony*, whom the sound of a Bagpipe would force presently to make water; adding, that a Person disobligh'd by this man, and resolving to be merrily revenged on him, watched a time when he sat at a Feast so as he could not well get out, and brought a Bagpiper to play unawares behind him; which he did so unluckily, that the Musick had presently its wonted effect upon the poor Knight, to his great Confusion and the laughter of the Company. On which occasion I shall add, that I know a very Ingenious Gentleman, who has confes'd to me, that the noise of a running Tap is wont to have almost the like operation upon Him.

'Tis a common Observation, that the noise that an ungreased cart-wheel makes in grating against the axel-tree, and the scraping of a knife upon a plate of silver or pewter, and some other such brisk and acute Sounds, do so affect divers parts of the Head, as to produce that effect
that

even languid Local motion. 71

that is commonly called *setting the Teeth on edge*; which whether it proceed from any commerce between the Auditory Nerves, and those that are inservient to the motion we have mentioned, I leave Anatomists to consider. But these effects of acute sounds are much less considerable than that which I elsewhere relate of an Ingenious Domestick of mine, who several times complained, that the tearing of brown paper made his Gums bleed: which argued that the sound had an operation not onely upon the nervous and membranous parts, but the blood and Humours themselves.

Sir Henry Blunt, in his voiage to the *Levant*, giving an account of what he observed in *Egypt*, has, among other remarkable things, this passage: Many rarities of Living creatures I saw in *Gran Cairo*, but the most ingenious was a nest of four-legged Serpents of two foot long, black and ugly, kept by a Frenchman, who when he came to handle them, they would not endure him, but ran and hid

in their hole ; then would he take his Cittern and play upon it : They, hearing his Musick, came all crawling to his feet, and began to climbe up him, till he gave over playing, then away they ran.

This recalls to my mind, what some men of repute, and particularly the Learned *Kircherus*, relate concerning a great Fish, in or about the Streights that sever *Sicily* from *Italy*, which is said to be much affected with a peculiar kind of Tune, (harsh enough to Humane ears) by which the Mariners are wont to allure it to follow their vessels. And it may much strengthen the Conclusion maintained in this Chapter, if there be any certainty in the famous tradition, that the Lion is terrified and made to run away by the crowing of a Cock : I say, *if*, because though I doubt not but some peculiar kinds of Sounds, as well as of other sensible objects, may be particularly and exceedingly ungratefull to the Sensories of this or that peculiar kind of Animals, and consequently

to

to the ears of Lions; yet a late French Traveller into the *Levant* gives me cause much to question the matter of fact, affirming, that rowing along the brink of *Tigris* or *Euphrates*, (for I do not punctually remember which,) they were, for many hours in the night, terrified by Lions that attended them along the brink of the River, and would not at all be frighted by the frequent crowing of the Cocks that chanced to be in the passengers Boat. Of which unconcernedness of the Lions, our observing traveller took much more notice than the Lions appeared to do of the crowing of the Cocks. I might on this occasion say something of the received Tradition, that many sleeping persons will be more easily waked by being called upon by their own usual names, than by other names, though uttered with a louder voice. But this it may suffice to have mentioned; nor will I here insist on that more certain example of the operation of a Sound, which is as-

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forded by the starting of men or greater Animals, upon a surprizing, though not vehement, noise; though this oftentimes puts so many of the Spirits and Muscles into motion, that the whole bulk of the Animal is suddenly raised from the ground, which perhaps it could not be by the bare counterpoise of some hundreds of pounds: This, I say, I will not in this place insist on, because the *Phenomenon* seems to depend rather upon the loudness or acuteness of the sound, than upon any determinate modification of it, particularly relating to the *Animal* it self.

But the eminentest Instance of the efficacy of peculiarly modified Sounds upon disposed bodies, is afforded by what happens to those which are bit by a *Tarantula*. For though the bitten person will calmly hear divers other tunes, yet when a peculiarly congruous one comes to be plaid, it will set him a dancing with so much vigour as the spectators cannot but wonder at, and the dancing will
some-

sometimes continue many hours, if the Musick do so, and not otherwise. I know there are some that question the truth of the things related of these *Tarantati*, (as the *Italians* call them,) and I easily grant, that some Fictions may have been suffered to pass under the countenance of so strange a Truth. But besides the affirmations of some Learned men, (as well Physicians as others) my Doubts have been much removed by the Accounts I have received from an Ingenious Acquaintance of mine own, who at *Tarentum* it self, whence the Insect takes its name, and elsewhere, saw many bitten persons in their dances, some in publick and some in private places, and amongst the rest a Physician, on whom the tune that fitted his distemper had the same operation as on the other Patients. And the Learned *Epiphanius Ferdinandus*, who practised Physick in *Apulia* and *Galabria* for many years, not onely delivers upon his own personal observation, several Narratives of the effects

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effects of Musick upon the *Tarantati*,
but invites any that may doubt of the
truth of such Narratives to repair
to him at a fit season, undertaking to
convince them by ocular Demon-
stration.

I know a very honest and sober
Musician, who has divers times af-
firmed to me, that he could at plea-
sure, by playing a certain Tune,
(which he acquainted me with, and
which did not much move others)
make a person (whom he named to
me) weep, whether she would or
no. And I might add, that when I
have been taking Physick, or am any
thing feverish, the repetition of two
verses of *Lucan* seldom fails (as I
have often tried) of producing in me
a chilness, almost like that, but fainter,
that begins the fit of an ague. But
on this Instance I look not as a strong
proof of the Physical efficacy of
Sounds; because those two verses
having been emphatically read, when
divers years agoe I lay sick of a slow
fever, and could not rest, they made
so

even languid Local motion. 77

so strong an impression on me, that whenever I am under a Discomposure any thing near like that, that then troubled me, those verses revive, as'twere, in my brain and some other parts that disposition, or rather indisposition, with which my first hearing of those verses was accompanied.

It may be the less admired, that the vibrating motion of the Air, that produces sounds, should have such effects upon disposed Organical bodies, since Light it self, which either consists of briskly moving *effluvia* far more subtile than aerial corpuscles, or is propagated by the pulse of a far more subtile body than Air, may have a notable operation upon disposed bodies. For we commonly observe, that the Sunbeams, by beating upon the face or eyes of some that come suddenly out of a shaded place into the Light, presently make them sneeze; which you know is not done without a vehement motion of divers parts of
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Of the great Effects of
the body. And though Colour be but
a modification of Light; yet, besides
that 'twas anciently a practice, as the
History of the *Macchabees* informs
us, to shew red objects to Elephants,
to make them more fierce, 'tis a fa-
miliar observation, that red cloaths
do offend and irritate Turkey-cocks.
And that is more remarkable, which
is related by the very Learned Phy-
sician *Valesius*, of a person that he knew,
who, if he looked upon red objects,
would not onely have his Eyes offen-
ded, but was subject to an effusion
of Humours in the neighboring parts.

CHAP.

CHAP. VII.

Observat. VI. *Men suspect not what efficacy the Invisible motions of Fluids may have, even upon inorganic bodies, upon the score of some determinate Congruity or relation betwixt a peculiar Texture of the one, and the peculiar modification of the others motion.*

THough the Experiments delivered in the foregoing Chapter have, I presume, sufficiently manifested, that the modification given to the motions of the Air by sonorous bodies may have considerable effects upon Animals, in whose organized bodies the curiously contrived parts have an admirable connexion with, and relation to, one another, and to the whole Symmetrical fabrick they make up; yet, I fear, it will scarce seem credible, that sonorous motions of the Air, not very loud, should find, even in
bodies

bodies Inanimate and Inorganically, such congruous Textures and other Dispositions to admit their action, that even more languid Sounds, peculiarly modified, may sensibly operate upon them, and much more than sounds that are louder and more vehement, but not so happily modified. To make this good by particular Experiments, I shall begin with that, which, though the effect may seem inferiour to that of most of the others, I judge fittest to manifest, that the produced motion depends upon the determinate modification of that of the impellent Fluid.

That a certain impulse of Air, made by one of the Unison-strings of a Musical Instrument, may suffice to produce a visible motion in another, is now become a known experiment; of the Cause and some unobserved Phænomena of which I elsewhere more fully discourse. But, that it may not be suspected in this case, that the shake of the untouched string is communicated to it by the propa-

propagated motion of the Instrument it self, to which the string, that is struck; is also fastned; I shall add, that, according to what I elsewhere relate, I found by trial purposely made; that a string of Wire, (which you will grant to be a more solid body than an ordinary Gut-string,) may be without another string brought to tremble by a determinate Sound made at a distance, which produced but such an impulse of the Air, as could neither be seen nor felt by the By-standers, nor would communicate any sensible motion to the neighbouring strings. 'Tis true, that in this case the string, in which the trembling was produced, was a single, long, slender and springy body, fastned at both ends to a stable one; and therefore it may seem altogether groundless to expect, that any thing like this effect should be by the same cause produced in bodies that do not appear so qualified. But, as we elsewhere shew, that a certain degree or measure of tension is in order

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der to this Phænomenon the principal Qualification, without which all the other would be unavailable; perhaps 'twill not be absurd to enquire, *whether*, in bodies of a very differing appearance from strings, the various Textures, Connexions, and Complications, that Nature or Art, or both, may make of the parts, may not bring them to a state equivalent to the Tensions of the strings of Musical Instruments, whereby divers of the mentioned parts may be stretched in the manner requisite to dispose them to receive a vibrating motion from some peculiar Sounds: And *whether* these trembling parts may not be numerous enough to affect their neighbours, and make, in the body they belong to, a tremulous motion discernible, though not by the Eye, yet by some other sense. This conjecture or inquiry you will, I hope, have the less unfavourable thoughts of, when you shall have considered the following Experiments.

I remember, that many years agoe
I found

even languid Local motion. 83

I found by trial, that, if a somewhat large and almost hemispherical Glasse, though not very thin, were conveniently placed, a determinate sound, made at a convenient distance from the concave surface of the Glasse, would make it sensibly ring, as a Bell does a while after it has been struck. But this noise was the effect of a determinate sound; for, though the voice were raised to a higher tone, or if the sound were made louder, the same effect would not insue. I remember also, that, some years after, I observed, that large empty drinking-glasses of fine white metal had each of them its determinate Tension, or some disposition that was equivalent as to our purpose. For, causing the strings of a Musical Instrument to be variously screwed up, and let down, and briskly struck, we found, as I expected, that the motion of one string, when 'twas stretched to a certain note or tone, would make one of the Glasses ring, and not the other; nor would the sound of the

G 2 same

same string, tuned to another note, sensibly affect the first Glasse, though perhaps it might have its operation upon another. And this Circumstance is not, on this occasion, to be omitted, that, after we had found the tone proper to one of the Glasses, and so tuned the string, that, (I say) when that was struck, the Glasse would resound. Having afterwards broken off a part of the foot of the glass, yet not so much but that it continued to stand upright, the same sound of the string would no longer be answered by the Vessel, but we were obliged to alter the tension of the string, to produce the former effect. The Learned *Kircherus*, as I have been informed, somewhere mentions a correspondence between some liquours and some determinate sounds; which I suppose may be true, though the triall did not succeed with me, perhaps for want of such accommodations for so nice an Experiment as I could have wished, but could not procure: But if you can, you will oblige

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lige me to make the trials so as to satisfy your self and me, whether the agitation of the liquor be caused immediately by the motion of the Air, or be communicated by the intervention of the tremblings of the Vessel.

An Artist famous for his skill in making Organs, answered me, that, at some stops of the Organs, some seats in the Church would tremble. But, because I suspected by his Relation, that the greatness of the sound chiefly effected it, because, when that Pipe, which they call the open *Diapason*, sounds, the chair or seat, on which the Organist sits, and perhaps the neighbouring part of the Organ trembles; I shall add, that I have divers times observed certain sounds of an excellent Organ to make not onely the seat, I sat on in the Church, tremble under me, but produce an odd tremulous motion in the upper part of my Hat, that I could plainly feel with my hands. And that, which makes me apt to believe that this effect depends upon the de-

G 3 ter-

terminate tone, rather than upon the loudness of the sound, is, that I have oftentimes felt, and diligently observed such a kind of motion in the upper part of my Hat, upon the pronouncing of some words in ordinary discourse; in which case the effect could not with probability be referred to the greatness of the Sound, but its peculiar fitness to communicate such a motion to a body so disposed.

Nor is it onely in such small and yielding bodies, as Hats and Strings, that Sounds that are not boisterous may produce sensible effects, for, if they be congruous to the Texture of the body they are to work on, they may excite motions in it, though it be either solid or very bulky: of which I shall here subjoyn a couple of instances.

An ancient Musician affirmed to me, that, playing on a Base-viol in the chamber of one of his Scholars, when he came to strike a certain Note on a particular string, he heard an odd kind of jarring Noise, which he thought

thought at first had either been casual, or proceeded from some fault in the string; but, having afterwards frequent occasion to play in that same room, he plainly found, that the Noise, he marvelled at, was made by the tremulous motion of a Casement of a window, which would be made to tremble by a determinate sound of a particular string, and not by other Notes, whether higher or lower.

To this first Instance I shall add the second, which, I confesse, I was not forward to believe, till trial had convinced me of the Truth; and I scrupled it the rather, because, if the reflexion of determinate Sounds should appear to proceed from the peculiar kind of tremulous motion into which the parts of the resonant body are put, it may incline men to so great a Paradox, as to think, that such a motion of the Air as our Bodies do not feel, may produce a trembling in so solid a body as a Stone-wall of a great thickness. The Experiment or Observation it self I shall give you

Of the great Effects of
in the same words I set it down some
hours after I made it, which were
these.

Yesterday I went to satisfy my
self of the truth of what had been
told me by an ancient Musician, to
whom I had been relating what I had
observed of the effects of some de-
terminate Sounds even upon Solid
bodies, and of whom I enquired, if
he had met with any thing of the like
nature: taking him along with me,
I found, that though the place be but
an Arch, yet it would not answer to
all notes indifferently, when we stood
in a certain place, but to a determi-
nate Note, (which he afterwards told
me was *Ce fa ut* a little flatted,) to
which note it answered very reso-
nantly, and not sensibly to others,
which we made trial of, whether
higher or lower than it; and, (which
added to the strangeness,) when I
made him raise his voice to an
Eighth, as consonant as those two
Sounds are wont to be in all other
cases, the vaulted Arch did not ap-
pear

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pear to us affected with the Note. The Musician added, that he had tried in most Arches all about the City, and could not find such a peculiarity in them, as being to be made resonant by all Notes or Sounds indifferently that were strong enough; and also, that as this Arch for this hundred years has been observed to have this property, so an ancient and experienced Builder informed him, that any Vault that were exquisitely built, would peculiarly answer to some determinate Note or other.

CHAP.

CHAP. VIII.

Observat. VII. *Men look upon divers Bodies as having their parts in a state of absolute Rest, when indeed they are in a Forced state, as of Tension, Compression, &c.*

THis Observation will probably seem paradoxicall. For, when an intire Body, especially if it be of a solid Consistence, and seem to be of an homogeneous or uniform matter, appears to be movelesse, we are wont to take it for granted, that the parts, which that body is made up of, are perfectly at Rest also. But yet this will scarce be thought a reasonable supposition, if we do but rightly consider some obvious *Phænomena*, which may teach us, that, whilst a whole Body, or the superficies that includes it, retains its figure, dimensions and distance from other stable Bodies that are near it, the Corpuscles that compose it may have various

various and brisk motions and endeavours among themselves. As, when a bar of iron or silver, having been well hammered, is newly taken off of the Anvill; though the Eye can discern no motion in it, yet the touch will readily perceive it to be very hot, and, if you spit upon it, the brisk agitation of the insensible parts will become visible in that which they will produce in the liquor. Besides, when the Lath of a Cross-bow stands bent, though a man do neither by the Eye nor the Touch perceive any motion in the springy parts, yet if the string be cut or broken, the sudden and vehement motion of the Lath, tending to restore it to the figure it had before it was bent, discovers a springiness; whence we conclude it was before in a state of violent Compression. And, though the string of a bent Bow do likewise appear to be in a state of Rest; yet, if you cut it asunder, the newly made extreams will fly from one another suddenly and forcibly enough
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to manifest, that they were before in a violent state of Tension. And on this occasion I could add divers Instances taken not onely from the works of Art, but those of Nature too, if they did not belong to another paper: But, one sort of Observations 'twill be proper to set down in this place; because in those already mentioned, the bow and string were brought into a violent state by the meer and immediate force of man. I shall therefore add, that there are divers bodies, in which, though no such kind of force appears to have antecedently acted on them, we may yet take notice of a state of violent Compression or Extension, and a strong endeavour or tendency of the parts, that to the Eye or the Touch seem at rest, to shrink or to fly out; and this endeavour may in some Cases be more lasting and more forcible than one would easily suspect or believe. But examples of this kind you must not expect that I should give you out of *Classick* Authors,

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thours, since in them 'tis like you have not met with either an Instance or a Conjecture to this purpose ; but some few things that I tried my self, and some others that I learnt by Inquiry from some Tradesmen , whom I judged likeliest to inform me , I shall briefly acquaint you with.

I have sometimes observed my self, and have had the Observation confirmed to me by the ingeniouser Traders in Glas; That a Glass, that seemed to have been well baked, or nealed, (as they call it) would sometimes, many days or weeks, or perhaps months, after it is taken from the fire, crack of its own accord ; which seems for the most part to happen upon the score of the strong, but unequall, shrinking of the parts of the Glasse. And the Glas-men will tell you, that, if they take their Glasses too hastily from the fire, not allowing them leisure to cool by degrees, they will be very apt to crack. But I remember, that, to satisfy some Ingenious

genious men, I devised a way of exhibiting a much more quick and remarkable *Phænomenon* of that kind. Having made then, by a way I elsewhere teach, a flat Lump of metal-line Glafs, two or three or four times as thick as an ordinary Drinking-glass, I observed, as I expected, that, though it had been melted in a very gentle fire, its very fusible nature needing no other, and though it were removed but very little from the fire, it was so disposed to shrink upon a small degree of Refrigeration, or rather abatement of Heat, that, before it was sensibly cold, it would crack with a noise in so vehement a manner, that, notwithstanding the ponderousness of the matter, which had been purposely laid upon a Level, parts of a considerable bulk, weighing perhaps some Drums, would fly, to a not inconsiderable distance from one another. And this Experiment I took pleasure to make more than once. And if you will be content with an Instance which,

which, though otherwise much inferior, may not be unwelcome, for its being easily and readily made; I shall offer you one that I have often repeated. Take a piece of Copper, (if the Plate be thick, 'tis so much the better,) and, having thoroughly brought it to a red or white Heat among kindled Coals, take it from the fire, and when it begins to cool a little, hold it over a sheet or two of white Paper, and you will perceive good store of flakes to fly off, not without some little noise, one after the other, and sometimes perhaps as far as the farthestmost edges of the paper; which flakes or scales seem by their brittleness and colour, to be but parts of the surface of the metal vitrified by the vehement action of the fire, and afterwards by a too hasty refrigeration shrinking so violently, as to crack and leap from one another, like the contiguous parts of the string of a Viol or other Musical Instrument, that breaks by the moisture of the Air. And on
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this occasion I shall add, that, having afterwards inquired of an expert Artificer, that made metalline Concaves, about the shrinking of his mixtures of metalls, he confessed to me, that he usually observed them to shrink upon Refrigeration. And the like I my self have observed in Iron of a great thickness, and purposely fitted to a hollow body of metall, which it would not enter when it was ignited, though it would when 'twas cold. But to shew you by a notable Instance or two, both that Metals may shrink, and that they may doe so with a very considerable force, I shall add, that I found by inquiry, that the lately mentioned Artificer, after he had made some large Concaves of an unfit mixture of metals, and having removed them from the fire, had been very carefull to keep the cold Air from them, lest they should cool too hastily, observed yet to his great loss, that, when they came to be further refrigerated, they would (perhaps after three hours) crack with a great noise, though

though this metalline mixture were perchance harder than Iron, and three or four times as thick as common Looking-glasses. But the misfortune of another Tradesman afforded me a yet more considerable *Phenomenon*. For this excellent Artificer, whom I often employ, and with whom I was a while since discoursing of these matters, complain'd to me, that, having lately cast a kind of Bell-metall upon a very strong solid Instrument of Iron of a considerable superficial *Area*, though the metal were suffer'd in a warm room to cool, from about eight a clock on Saturday night till about ten or twelve on Monday morning, and were then (which is to be noted) considerably hot to the touch; yet it cool'd so far, that, shrinking from the Iron that would not shrink with it, the Bell-metall cracked in divers places with noises loud as the Report of a Pistoll, though the metall, he affirm'd to me, was an inch and half, or two inches thick. And the same

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person shewed me a large Cylinder of Iron, about which, for a certain purpose, a Coat of Bell-metall had been cast some days before, on which (Bell-metall) there was a crack near one end made by the coldness of the Iron, though the thickness of the Bell-metall, as near as I could measure it, exceeded an inch, and (as the Workman affirmed) an inch and a quarter.

Nor is it onely in such mixtures as Bell-metall, which, though very hard, may be very brittle, but even in a metal that is malleable when cold, that the like Phænomenon may be met with, as I have been assured by another ingenious Artificer, of whom I inquired, whether he had taken notice of the shrinking of metalls; who affirm'd to me, that, having had occasion to cast about a Cylinder of Iron a ring or hoop of Brass, he found to his trouble, that, when the metall began to cool, the parts shrunk from one another so as to leave a gaping crack, which he was fain to fill

fill up with soulder quite cross the breadth of the ring, though this were above an inch thick.

I should not, *Pyrophilus*, have in this Chapter entertained you with more Experiments of others than of my own, if I had the conveniency of living near Founders of metall, as the Tradesmen had whose Observations I have recited, and whose sincerity in them I had no cause to question. And both their Experiments and mine seem to teach, that a body may be brought into a state of Tension, as well by being expanded and stretch'd by the action of the fire upon the minute parts, as by the action of an external Agent upon the intire body. And, to speak more generally, the state of violent Contraction and Compression may not unfitly be illustrated by a Bow that is bent. For, as the Bow it self is brought to a state of Compression by the force of the Archer, that bent it; so by the Elastical force of the bent Bow, the string is brought into a violent state

of Tension, as may be made evident by the cutting off the string in the middle; for then both the Bow will fly suddenly outwards, and the parts of the string will swiftly and violently shrink from one another. And according to this Doctrine, the effect of other bodies upon such as are thus brought into, what men call, a Preternatural state, is not to be judg'd barely according to usual measures, but with respect to this latent Disposition of the Patient: as, for instance, though the string of a Viol not screw'd up, will not be hardned by the vapours that imbue the Air in moist weather; yet a neighbouring string of the same Instrument, though perhaps much stronger, being screw'd up, and thereby stretched, will be so affected with those vapours, as to break with noise and violence. And so when one part of a piece of Glass is made as hot as can be, without appearing discolour'd to the Eye, though a drop or two of cold water have no effect upon the other part of the

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even languid Local motion. 101

the same Glasse, yet if it touch the heated part, whose wonted extension (as I have elsewhere proved) is alter'd by the fire that vehemently agitates the component particles, the cracking of the Glass will almost always presently ensue. M. 100. I. 101.

If against these Instances it be alledged, that it is possible to assign another cause of the seemingly spontaneous breaking of the bodies mention'd in this Chapter, than that which I have propos'd, it will not much concern this Discourse to examine the Allegation; for, whatever the latent Cause of the Phenomena may be, the manifest Circumstances of them suffice to shew, that bodies, which, as to sense, are in a natural state of Rest, may be in a violent one, as of Tension, and may have, either upon the score of the texture of the parts among themselves, or upon that of some interfluent subtil matter, or some other Physical Agent, a strong endeavour to fly off or recede from one another, and that,

in divers bodies, the cause of this endeavour may act more vigorously than one would easily believe: and this suffices to serve the turn of this Discourse. For I presume that a person of your Principles will allow, that Local Motion must be produc'd by Local Motion, and consequently, that, without a very strong, though invisible and unheeded one, such hard and solid bodies as thick pieces of metall could not be made to crack.

I know not whether I may on this occasion acquaint you with an odd Relation I had from a very honest and credible, as well as experienced, Artist, whom I, for those reasons, have several times made choice to deal with about precious Stones, and other things belonging to the Jewellers and Goldsmiths trades. For, considering with him one day a large lump of matter, which contained several Stones that he took for coarse Agats, and which were joyned together by a Cement, that in most places was harder than most ordina-
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ry Stones, I perceived that there remained divers pretty large cavities in this Cement, which seemed to have contained such Stones as those that yet made parts of the lump. Upon which occasion he affirmed to me, that several of the Stones grew whilst they were lodg'd in those cavities. And when I told him, that, though I had been long of an opinion, that Stones may receive an increment after their first formation, yet I did not see how any such thing appeared by those we were looking upon : He gave me in many words an account of his Assertion, which I reduced to this, that the Stones he spoke of, did, after they were first formed, really tend to expand themselves by virtue of some Principle of growth, which he could not intelligibly describe ; but that these Stones being lodg'd in a Cement extreamly hard, and therefore not capable of being forced to give way, their expansive endeavour was rendered ineffectual, but not destroyed : so that when afterwards these

Stones came to be taken out of the Cement wherein they were bedded, and to whose sides 'tis like they were not exquisitely congruous, the compressed Stones, having their sides now no longer wedged in by the harder Cement, quickly expanded themselves, as if 'twere by an internal and violently compressed spring, and would presently burst asunder, some into two, and some into more pieces: of which he presented many to his friends, but yet had reserved some, whereof he presented me one, that I have yet by me, together with some of the mass, whose Cement I find to bear a better polish than marble, and to be very much harder than it. And, in answer to some questions of mine, he told me, that he had taken up these Stones himself, naming the place to me, which was not very far off, and that he observed all that he told me himself, and more than once or twice, and that I needed not suspect, as I seemed to doe, that 'twas the strokes employed to force the
Stones

Stones out of their Beds, that made them break. For, besides that many of them, which (it seems) were not compressed enough, did not break, several of those, that did, were taken out, without offering them any such violence, as that their bursting could with any probability be imputed to it.

by which many motions may be
produced, which are not
produced from the same
cause, and among the parts
of the same body.

His Observation is like to be
much more readily understood
if we are aware, and therefore shall
say a few words of the following

CHAP.

We could not have a large drop
which the movable part to be easily
moved to and fro in the container

to receive it, in that part of the in-
strument that was not to be broken
And though the motion of the Key

CHAP. IX.

Observat. VIII. One main cause why such Motions as we speak of are overlook'd, is, That we are scarce wont to take notice but of those motions of Solid bodies, wherein one whole Body drives away another, or at least knocks visibly against it, whereas many effects proceed from the intestine motions produced by the external Agent, in, and among, the parts of the same body.

THis Observation is like to be much more readily understood than granted, and therefore I shall offer by way of proof the following Experiments.

We caus'd in a large brass Stop-cock the movable part to be nimbly turned to and fro in the contiguous cavity of that part that was made to receive it, in that part of the Instrument that is wont to be kept fixt. And though this motion of the Key were

were made onely by the bare hand, yet in a short time the mutual attrition of the contiguous parts of the Instrument made so brisk an agitation in the other parts, that the incallescence made the metal it self to swell, insomuch that the Key could no more be turned, but remained fixt, as if it had been wedged in, so that, to make it work as before, it was necessary by cooling it to make it shrink a little, and so take off the mutual pressure of the Key, and the other part of the Stop-cock. Nor is this to be looked on as a casual Experiment; for, besides that it was made more than once, and is very analogous to some other trials of mine; I found, that a maker of such Instruments complained to me, that he was several times forced to intermit his work, and plunge his Instrument in cold water, before he could, by grinding, adjust the Key to the cavity it ought to fit.

Yd presume I need not take notice to you, that this Experiment confirms what

what I elsewhere mention of the dilatation of metals themselves by Heat, and therefore I proceed to the next Instance.

This is afforded by the known Experiment of passing one's wetted finger upon the orifice of a Drinking-glass almost fill'd with water. For, though the Eye does not immediately discern any motion, that, by reason of the pressure of the finger, is made by one part of the glass upon another; yet, That a vibrating motion is thereby produced, may be argued by the dancing of the water, especially that which is contiguous to the prest sides of the glass, by which 'tis oftentimes so agitated, that numerous drops are made to leap quite over, and others are tossed up to a good height into the Air. And that there may be considerable motions in the sides of the glass, whilst it does not break in pieces, we may probably guess by this, that, in Drinking-glasses artificially cut by a spiral line, both I, and others, have
often

even languid Local motion. 109

often found by trial, that, a glass being dextrously inverted and shaken, the parts will vibrate up and down so manifestly, as sometimes to lengthen the glass, by my estimate, a quarter of an inch or more, and yet, the glass being set again upon its foot, it appeared that it had not been hereby at all injured.

That two pieces of Iron or Steel, by being strongly rubbed against one another, will at length acquire a temporary Heat, is not hard to be believed: but that an edg'd Tool of hardened Steel should, by having its edge rubbed against, have a manifest and permanent change made in its Texture, you did not perhaps suspect; and yet, having had the Curiosity to cause some metals, and particularly Iron and Steel, to be turned by an excellent Artificer, I learned partly by his experience, and partly by my own, that the edge of the Steel-tool, with which he by degrees shaved off the protuberant parts of the metal, would be so heated and agitated, that,

that, in no long time, if care were not taken to prevent it, the tool would be brought to look of blewish and yellowish colours, and, permanently losing its former temper, would become so soft, as to be uselesse for its former work, unlesse it were again artificially hardened: and therefore, to prevent the trouble of tempering his tools again, this Artist, from time to time, dipt it, when it began to grow too hot, into a certain liquour, which he affirms, upon much experience, to have a peculiar fitness for that purpose.

Nor is it always necessary that the body, that makes the parts of an inanimate body work considerably on one another, should be either very hard, or impetuously moved. For, I remember, that, having once by me some short bars of fine Tin, I resolved to try whether, meerly with my naked hands, (which you know are none of the strongest or hardest,) I could not procure a considerable internal Commotion among the parts; and

even languid Local motion. III

and accordingly, laying hold on the two ends of the bar with my two hands, I slowly bent the bar towards me and from me two or three times, and having by this means broke or cracked it in the midst, I perceived, as I expected, that the middle parts had considerably heated each other.

What use may be made of this Experiment in the search of the hidden cause of Elasticity, would be less properly considered in this place than in another. But since I have named that Quality, I shall take this rise to intimate, that if the restitution of a springy body, forcibly bent, proceed onely (as some Learned Moderns would have it) from the endeavour of the compressed parts themselves to recover their former state, one may not impertinently take notice of the Elasticity that Iron, Silver and Brass acquire by hammering, among the Instances that shew what in some cases may be done by a motion wherein the parts of the same body are, by
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an almost unheeded force, put to act upon one another. But if Springiness depend chiefly upon the pervasion of a subtile matter, as the *Cartesians* would have it, then the Instances will properly belong to another Subject.

§ The foregoing Examples may also suffice to make out (what I am unwilling to refer to another Head) this subordinate Observation, That men are more usually than justly prepossessed with an opinion, that nothing considerable is to be expected from the motion of a body against another, unless the former do make a manifest percussive or trusive of the latter. But, because this prepossession especially prevails in cases where the body that is by friction or attrition to affect the other, is itself soft or yielding, I shall on this occasion add a few Instances to remove this Prejudice.

An Artist, eminent for grinding of Optical glasses, confessed to me, that sometimes when he went about
to

to polish his broader glasses, though but upon a piece of Leather sprinkled with Puttee, that friction did so heat or otherwise agitate the parts of the glass, as, to his great loss, to make it crack from the edge to the middle; which seemed the more strange, because we see, what intense degrees of Heat glasses will endure without cracking, if the fire be but gradually applied, as this Artist's glasses must have been gradually heated.

But I think it worth inquiry, whether in this case the whole work be performed by meer Heat, and whether there intervene not a peculiar kind of motion, into which some bodies are disposed to be put by a peculiar kind of friction, which seems fitted to produce in manifestly springy bodies, and perhaps in some others, (of which divers may be springy that are not commonly taken to be so,) such a vibrating or reciprocal motion, as may have some notable effects, that are not wont to be produced by

moderate Heats, nor always by intense ones themselves. The trembling of the parts of a Drinking-glass, and the visible vibration of the long and great strings of a Base-viol, upon peculiar sounds, may give some countenance to this conjecture. And that in some bodies there may be such a tremulous motion produced, by rubbing them upon so soft a thing as Wool, or upon a piece of Cloath, I tried by this Experiment:

We cast into a hollow Vessel, very smooth within, and of an almost Hemispherical figure, severall ounces of good melted Brimstone, and having suffered it to cool, and taken it out, the Convex surface, as had been desired, came off well polished; then this conveniently shaped lump, which had (if I well remember) four or five inches in Diameter, being briskly rubbed in the same line forwards and backwards, upon a Cushion or some such woollen thing, in a place free from other noises, I could, by holding my ear to it, and attentively listening,

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stening, plainly hear a crackling noise made by the agitated parts, which continued a brisk, and, as I supposed, a vibrating motion for some time after the friction was ended.

That there may be a considerable Commotion produced among the internal parts of bodies, by rubbing them even against soft bodies, I have divers times observed, by the sulphureous steams that I could smell, if, after having a little rubbed a lump of good Sulphur upon my Cloaths, I presently held it to my nose. Which brings into my mind, that I have had the like effect from much harder and closer bodies than Sulphur, when they were rubbed upon bodies that were so too. For having purposely taken hard Stones cut out of mens Bladders, and rubbed a couple of them a little against one another, they quickly afforded, as I expected, a rank smell of stale Urin.

That Diamonds themselves will, by rubbing upon woollen cloaths, be made Electrical, seems to argue, that

even Their parts are set a moving: And that the Commotion reaches to the internal parts, I am the more apt to think, because I have a Diamond, that, if I rub it well and luckily against my Cloaths, will, for a little while, shine or glimmer in the dark; which is the same Phænomenon that I elsewhere relate myself to have produced in the King's larger Diamond, by giving it one brisk stroke with the point of a bodkin, where the Light that presently appeared in the Gem, seemed not referable to any thing so likely as the sudden Commotion made in the internal parts of that peculiarly constituted Stone.

What a peculiar modification of motion, distinct from its degrees of *Impetus*, may doe in Fluid bodies, we have formerly in this Essay taken notice of. But perhaps it may be worth while to enquire, what kinds there are of it, and what effects they may have in the parts of Solid bodies themselves. For I have observed,

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ved, that though those Stones that the *Italian* Glas-men use are very hard, and, if I misremember not, have several times afforded me sparks of fire by Collision; yet, by rubbing them a little one against another, I found, that such an agitation was made in their parts, as to make them throw out store of foetid exhalations: And 'tis possibly to the stony Ingredient that Glas owes the Quality I have observed in it, and elsewhere mentioned, of emitting offensive steams. And 'tis remarkable to our present purpose, that, though so vehement an agitation of the parts, as is given to Glas by Heat, when 'tis made almost red-hot in the fire, does not make it sensibly emit odours; yet barely by dextrously rubbing two solid pieces of Glas against one another, one may, in a minute of an hour, make those fixed bodies emit such copious steams as I found, not onely sensibly, but rankly, foetid; though one would think those stinking exhalations very indisposed to be forced off, since they

118 Of the great Effects of

were not expelled by the vehement fire, that the Glass long endured in the furnace where 'twas kept melted.

There are few things that shew better, both how the parts of Inorganical bodies communicate their vibrating motions to one another, and how brisk those motions are, than that which happens upon the striking of a large Bell with a Clapper or a Hammer. For though the stroak be immediately made but upon one part; yet the motion, thereby produced, is propagated to the opposite, and the successive vibrations of the small parts do, even in so solid and close a body as Bell-metal, run many times round; as may appear by the durability of the ringing noise, which seems plainly to proceed from the circularly successive vibrations of the parts, which, unless they briskly tremble themselves, can scarcely be conceived to be fitted to give the Air that tremulous motion, whose effect on the Ear, when the first and
loud

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loud noise, made by the percussion, is past, we call Ringing. And this motion of the parts of the sounding Bell may be further argued by this, that, if the finger, or some other soft body, be laid upon it, the sound will be checked or deaded, and much more, if a broad string, though of a soft substance, be tied about it. And not onely an attentive Ear may often make us guess, that the ringing sound is produced by a motion propagated circularly in the Bell, but this vibrating motion may sometimes be also felt by the tremulous motion communicated by the trembling parts of the Bell to the finger, that is warily applied to it. That this motion passes in a round, from one side of the Bell to the other, seems manifest by the great difference of sound, especially in regard of ringing, that may be observed in a sound Bell, and in a crack'd one; where yet all the matter and the former figure are preserved, onely the intireness or continuity, which is necessary to the circu-

lation (if I may so call it) of the tremulous motion, is at the Crack stopt or hindred. And that the motion of the parts is very brisk, may be guessed partly by what has been said already; but much more if that be true, which, not onely is traditionally reported by many, but has been affirmed to me by several Artificers that deal in Bells, who averred, as an experienced thing, That if a conveniently sized Bell were bound about, any thing hard, with a broad string, and then struck with the usual force, that it would otherwise bear very well; that percussion would break it, giving a disorderly check to the brisk motion of the parts of the Bell, whereof some happening to be much more (and otherwise) agitated than others, the force of their motion surmounts that of their Cohesion, and so produces a Crack.

But, in regard great Bells are not easie to be procured, nor to be managed when one has access to them, I shall add, that I took the Bell of a
large

even languid Local motion. 121

large Watch, or very small Clock made of fine Bell-metall, which had no handle or other thing put to it, save a little Bodkin or skiver of wood, whose point we thrust into the hole that is usually left in the middle of the *Bass*; and this sharp piece of wood serving for a handle to keep the Bell steady enough, we placed in the cavity of it, near the edges, (for that Circumstance must not be omitted,) some black mineral Sand, or, in want of that, some small filings of Steel or Copper, or some other such minute and solid Powder, which yet must not be too small, and then striking moderately with the Key against the side of the Bell, we observed, (as we expected) that, whilst it continued briskly ringing, it made many of the filings to dance up and down, and sometimes to leap up, almost like the drops of Water, formerly mentioned to skip, when the brim of the Glass was circularly prest by the wetted finger. Which prompts me to add, that, having put a middle-sized

sized drop of water (for in this case the quantity is a considerable Circumstance) near the lower edge of the Bell, 'twas easie to make it visibly tremble, and be as it were covered over with little waves, by a somewhat brisk stroke of the Key on the opposite side. And this effect was more conspicuous, when a very large drop of water was placed near the edge, on the convex side of a hand-Bell, whose Clapper was kept from any where touching the inside of it. And to obviate their jealousy, that, not having seen the manner of the above-mentioned motion of the Sand, might suspect that 'twas produced by the impulse which the Bell, as an in-tire body, received from the percussion made by the Key, we several times forbore putting-in the filings, till after the stroke had been given; which satisfied the Spectatours, that the dancing and leaping of the minute bodies proceeded from the same brisk vibrations of the small parts of the Bell, which, at the same time
striking

even languid Local motion. 123

striking also the Air, produced a ringing sound, which might very well, as it did, out-last the skipping of the filings; the exceedingly minute particles of the Air being much more easily agitable, than the comparatively gross and heavy Corpuscles of the Powder. And this success our Experiment had in a Bell, that little exceeded an inch and half in Diameter.

And here, *Pyroph.* I shall put an end to this Rhapsody of Observations, hoping, that, among so many of them, some or other will be able to engage you, if not to conclude, yet at least to suspect, that such Local motions, as are wont either to be past-by unobserved, or be thought not worth the observing, may have a notable operation, though not upon the generality of bodies, yet upon such as are peculiarly disposed to admit it, and so may have a considerable share in the production of divers difficult *Phænomena* of nature, that are wont to be referred to less genuine, as well as less intelligible, Causes.

F I N I S.